Structural Analysis of Foreign Direct Investment Network in China

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Abstract—With the development of world economic integration, the international division of labor system is gradually changed. Foreign direct investment (FDI) is one of the important mechanisms in the international echelon transfer and dynamic migration of industries, contributing to the dynamic adjustment of international division of labor system. The paper analyzes the structures of associative relationships of China's regional behavioral associative networks of FDI based on the network analysis method. The results show that, firstly, the regional behavioral associative networks have the "Small World" feature and the investments distribute unevenly. Secondly, the "Western Expansion" effect brought by the adjustment of FDI's structures is establishing, but the inland transmission effect distinguishes between eastern, northern region and south region. Finally, the leading block of investors is consisting of Hong Kong, Japan and USA, while the leading block of investee takes the advantage of the inland transmission effect to promote a 'sandwich' mode of development among the eastern, middle and western regions.

Keywords: Networks; Topological structure; FDI; Community Detection;

1 INTRODUCTION

During the past decades, China has gone through a mega economic growth, which contributes a lot to FDI and International trade. This flow of capital, FDI, brings China huge opportunities for employment and taxations, as well as potential and effective spillovers. However, it is true that, the thrust of FDI is fading after the bloom of FDI, with the decline of growth of international commodity trade worldwide. Moreover, Chinese provinces, especially coastal provinces are suffering from the evacuation of FDI. Although the literature in the aspects have explored the determinants, location and drive of FDI activities among nations [1]-[4], they pay little attention to investigate the mechanism of investment choice between investors and investees. Only a small part of literatures covers the links between nations or sectors and nations. The linkages represent the choices and considerations among investors not only from the firms but also the nations. As argued, FDI originates from the initial nation to the destination connected by network edges, and this network can be detected from the past data. These results of detection can imply some useful suggestions for all actors in the network, but actually, it is vital for Chinese provinces to adjust the existed policies and incentive rules to attract FDI. Hence, based on network analysis method [5], this paper concentrates on the patterns and modes of network actors, including the investors and investees, to study the structural characteristics of the regional the behavioral associative relationship network of FDI in China.

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2 METHODOLOGY

2.1 Construction method of China's Regional Behavioral Associative Networks

The relationship of FDI is a set of relationships between investors and investees. It is a typical two-part network structure and can be represented by a weighted two-part graph. [6] Through mapping of bipartite relationships, the origin-origin and destination-destination one-mode networks can be drawn respectively, which can depict the behavioral associative relationship between investor and investee. It should be considered the edge weight (investment flow) when using "nation (region)-province (district)" two-mode data to analyze the behavioral associative networks of investor and investee. Therefore, this paper uses transferred version of minimums method based on mapping scheme by Dormann et al. [7] to conduct the network transfer. Besides, key information of transferred weighted undirected networks and build graded nets will be extracted in the following. Based on the graded network structure method of Peres et al. [8], the author rank weights of every node and choose top 10 edges of every node to form Top 10 network.

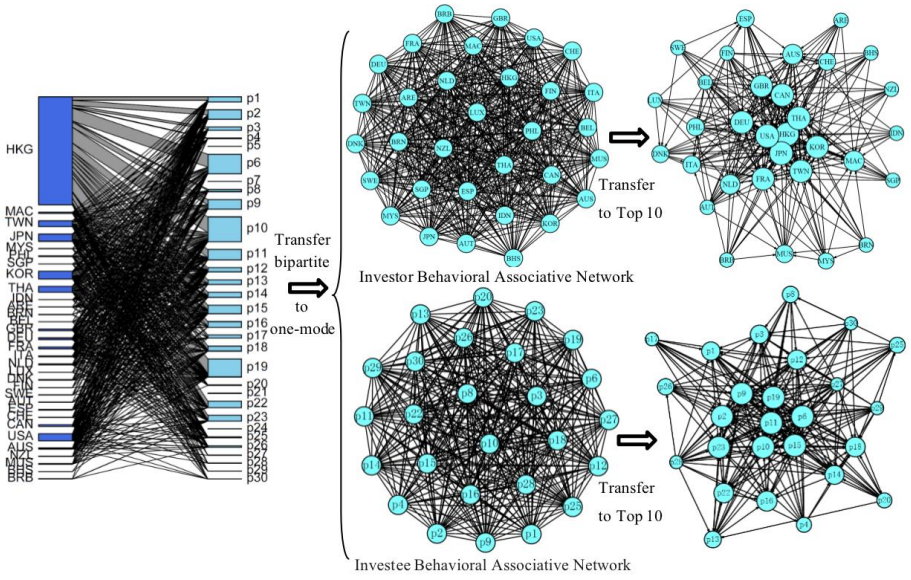

Figure 1. Establishment of Investor and Investee Behavioral Associative Networks

2.2 The Structure Feature of China's Regional Behavioral Associative Networks

2.2.1 Network Structure Index

a) Network density measures the incidence of networks for nodes. The effect is larger when the density is larger.

$$\text{Density} = \frac{1}{N(N-1)} \sum_{i=1}^{N} k_i \tag{1}$$

Where k_i represents the degree of node i and N is the number of nodes in network.

b) the average path length is used to estimate the minimum distance between node pairs. It reflects the dispersion degree of network nodes:

$$\mathrm{APL} = \frac{1}{\mathrm{N(N\text{-}1)}} \sum_{\mathrm{i,j \in N}} \mathrm{d_{ij}} \tag{2}$$

Where $\mathrm{d_{ij}}$ represents the distance between node i and node j, and N is the number of nodes in network.

c) Network reciprocity is the ratio of two-way edges on all edges, which represent whether the investor and investee behavior has high reciprocity.

$$\mathrm{Reciprocity} = \frac{\mathrm{e_q}}{\mathrm{E}} \tag{3}$$

Where E represents the number of all the edges in network and $\mathrm{e_q}$ is the number of quadratic edges.

d) Aggregation degree of network is measured by transitivity in general. It reflects one kind of typical characteristic, the region with same investor of investee may connect with each other.

$$\mathrm{Transitivity} = \frac{3 \times \mathrm{M_{triangles}}}{\mathrm{M_{triples}}} \tag{4}$$

Where $\mathrm{M_{triangles}}$ represent the number of triangles in network, and $\mathrm{M_{triples}}$ is the number of transitive triples.

e) the out-degree ($\mathrm{D_{out,i}}$) in graded networks is 10 while the in-degree of nodes is different, we consider the maximum in-degree ($\mathrm{D_{in,max}}$) and standard error of in-degree as indices of fluctuation of region behavioral associative networks. In the directed graph, $\mathrm{D}=\mathrm{D_{in,i}}+\mathrm{D_{out,i}}$, and $\mathrm{Std\_D_{in}} = \sqrt{\frac{\sum_{\mathrm{i=1}}^{\mathrm{N}} (\mathrm{D_{in,i}}\text{-}\mu_{\mathrm{in}})}{\mathrm{D\text{-}1}}}$, where μ_{in} is the arithmetic mean of node in-degree.

2.2.2 Node Centrality Analysis

a) In-degree centrality, it depicts the intensity of node in-degree to report the relative in-degree level:

$$\mathrm{C_D(i)} = \frac{\mathrm{D_{in,i}}}{\mathrm{N\text{-}1}} \tag{5}$$

where $\mathrm{D_{in,i}}$ represents the in-degree of node i.

b) PageRank considers the out-in degree of nodes. It adds weight into the consider structure to measure the importance of nodes. Also, the high-indices nodes are more important than the low-indices nodes. PageRank indices also reflect a flowing impact through the iteration character of algorithm different with other centralities.

$$\mathrm{PR_i(k)} = \sum_{\mathrm{j=1}}^{\mathrm{N}} \mathrm{a_{ji}} \frac{\mathrm{PR_j(k\text{-}1)}}{\mathrm{k_j^{out}}},\ \mathrm{i}=1,2,\cdots,\mathrm{N} \tag{6}$$

Where $\mathrm{a_{ji}}$ is the adjacency relation between node j and node i, and $\mathrm{k_j^{out}}$ is the sum of weight that node j points to other nodes.

2.3 Community detection of China's Regional Behavioral Associative Networks

This paper is going to establish diverse centrality indices distance matrix to measure the distance of nodes comprehensively and generally. [9] Among all these, the selection of indices concludes nodes' in-degree, betweenness, closeness, eigenvector centrality and PageRank value. Furthermore, the network of this paper is the investor and investee behavioral associative network. So it detects the classified associative situation of regions in the network. Hence, this paper applies bottom-up agglomerative hierarchical clustering method to analyze. Meanwhile, the author use the nearest neighbor rule to resolve the potential chaining structure in region behavioral associative networks to figure out the possible chaining associative effect between investor and investee.

3 FINDINGS

3.1 Descriptive Analysis

Based on equation (1) to (5), we calculate the whole structural feature of investor and investee behavioral associative networks (see in Table1). The results show that, from investor behavior associative network's perspective, first, the densities of network are below 0.4 which means there are still large expansion space to cooperate and investment among nations. Second, the APLs (average path length) are all smaller than 1.4, and the transitivity is higher than 0.68 averagely. The author can speculate that this network has feature of small world, in other words, one nation (region) can reach a consistent investment strategy with another nation (region) through existing investment relations. Moreover, the value of reciprocity is relatively low, which indicates the investors reciprocity is not good and there is certain competence among nations (regions). Through maximum in-degree and standard error of in-degree, it reflects those nations (regions) reached the maximum in-degree has appeared in investor behavioral associative network since 2005. From investee behavior associative network's perspective, the density is lower than that in investor network, which shows investee behavioral relations are more concentrative. What's more, the APL has been increasing year by year while the transitivity is in U shape, which is consistent with the feature of small world. However, with the enlargement of distance between distant provinces, and the similar provinces' agglomeration degree has increased. It represents the investee associative relations have large difference among provinces in different area. Additionally, even though the reciprocity of investee is higher than that of investor, they are both low in general. That is to say, investee behavior associative features accord with the willing of avoiding competence among investors. And there are few symmetrical investment-attracting behaviors. All the provinces (districts) can obtain investment-attracting opportunity and this asymmetry feature is decreasing gradually. Besides, the maximum in-degree in investee associative network is in U shape as well and it is near the peak value of 29 in 2005. Combined with decreasing in-degree standard error, it can be proved that the investee behavioral associative network has been expanded horizontally. Province in the center of investment-attracting has been reduced and the distribution of investment opportunity has been more and more equal.

Table 1 Feature Analysis of Investor and Investee Behavioral Associative Networks

Year / Indice	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Investor Behavioral Associative Network										
Density	0.315	0.372	0.342	0.342	0.351	0.349	0.342	0.331	0.330	0.338
APL	1.185	1.224	1.283	1.153	1.123	1.229	1.358	1.317	1.288	1.227
Reciprocity	0.359	0.304	0.336	0.330	0.322	0.324	0.336	0.348	0.343	0.328
Transitivity	0.678	0.749	0.692	0.699	0.678	0.682	0.663	0.647	0.644	0.669
Max_Din	29	30	30	30	31	31	31	31	31	31
Std_Din	11.764	11.772	12.321	12.456	12.903	12.632	12.260	12.054	12.692	12.295
Investee Behavioral Associative Network										
Density	0.299	0.299	0.332	0.317	0.334	0.326	0.322	0.313	0.321	0.325
APL	1.097	1.100	1.158	1.314	1.249	1.250	1.261	1.415	1.196	1.261
Reciprocity	0.423	0.423	0.381	0.413	0.385	0.394	0.400	0.426	0.394	0.396
Transitivity	0.702	0.708	0.704	0.701	0.666	0.685	0.679	0.694	0.721	0.761
Max_Din	25	25	27	26	28	27	27	26	26	25
Std_Din	11.050	10.993	11.208	10.473	11.739	11.023	11.388	10.275	10.323	9.992

Furthermore, the calculating results of in-degree centrality and PageRank are listed in Table2. It shows that, from investor's perspective, before 2005, nations whose centrality is larger than 0.5 mainly located in China's neighbors and Hongkong, Taiwan. Also, it concludes some developed countries in Western Europe like Netherlands, German and UK, as well as US and Canada in North America. After 2005, centrality of France, Italy and Sweden has been increasing. It shows these nations' investors expand the target market. China's neighbor investors' in-degree and centrality are both above 0.8, which occupied main part of FDI. Meanwhile, the centrality of Australia and New Zealand grow rapidly and the trend of investment-chasing has been formed. It can be found that due 2010, China's investor origins are still developed countries in Asian neighbors, Western Europe, North America and Oceania (only Thailand is developing country). Therefore, the author can judge that the investor behavior has certain geographical aggregation features. For another, from investee's perspective, China's investment-attracting level has great gap before 2005 because the centrality's distribution is concentrative with large difference. Core district of investment-attracting locate near the sea such as the Northeast, North China, East China, Southern part of China. But there are few investment-attracting activities in inland China. Liaoning, Jiangsu, Hubei, Guangdong and Shanghai are top 5 in in-degree centrality and PR value. After 2005, the strength of investment-attracting has enforced and some provinces' centrality has increased significantly. They are Jiangsu, Zhejiang, Shanghai, Tianjin and Shandong At the same time, some midland has formed certain investment-attracting relations in 2005 such as Anhui, Jiangxi, and Hunan. Thus midland and western land start to obtain the development opportunity with the growth of investment-attracting size. After that, investees in central status start to decrease their centrality. In general, investee behavioral associative relations concentrate from costal to inland.

Table 2 Analysis of Centrality of Investor and Investee Behavioral Associative Networks (top 50%)

Year / Nation	2001		2005		2010		Year / Nation	2001		2005		2010	
	PR	D_{in}	***PR***	D_{in}	***PR***	D_{in}		***PR***	D_{in}	***PR***	D_{in}	***PR***	D_{in}
HKG	0.14	0.94	0.14	1.00	0.14	1.00	DEU	0.06	0.87	0.07	0.81	0.05	0.84
MAC	0.01	0.10	0.01	0.35	0.03	0.45	FRA	0.03	0.45	0.14	1.00	0.14	1.00
TWN	0.11	0.94	0.09	1.00	0.09	0.84	ITA	0.02	0.39	0.04	0.74	0.05	0.81
JPN	0.13	0.94	0.14	0.97	0.11	1.00	NLD	0.04	0.52	0.01	0.16	0.01	0.13
MYS	0.01	0.16	0.01	0.19	0.01	0.03	CHE	0.01	0.03	0.01	0.06	0.01	0.13
PHL	0.01	0.06	0.01	0.03	0.01	0.13	CAN	0.02	0.65	0.00	0.03	0.01	0.10
KOR	0.07	0.74	0.08	0.90	0.11	0.84	USA	0.13	0.94	0.03	0.77	0.05	0.87
GBR	0.06	0.87	0.06	0.94	0.05	0.71	AUS	0.01	0.39	0.13	1.00	0.11	1.00
Year / Province	**2001**		**2005**		**2010**		**Year / Province**	**2001**		**2005**		**2010**	
	PR	D_{in}	***PR***	D_{in}	***PR***	D_{in}		***PR***	D_{in}	***PR***	D_{in}	***PR***	D_{in}
Peiking	0.06	0.62	0.04	0.45	0.02	0.28	Fujian	0.08	0.59	0.04	0.38	0.01	0.14
Hebei	0.04	0.83	0.01	0.48	0.01	0.28	Jiangxi	0.01	0.00	0.05	0.93	0.02	0.34
Liaoning	0.10	0.86	0.06	0.90	0.10	0.86	Shandong	0.13	0.76	0.10	0.72	0.07	0.59
Heilongjiang	0.01	0.10	0.01	0.07	0.01	0.10	Henan	0.01	0.03	0.01	0.03	0.06	0.48
Shanghai	0.10	0.83	0.13	0.90	0.08	0.79	Hubei	0.06	0.86	0.05	0.86	0.01	0.00
Jiangsu	0.12	0.86	0.10	0.97	0.11	0.86	Hunan	0.04	0.69	0.02	0.17	0.03	0.45
Zhejiang	0.08	0.76	0.09	0.97	0.08	0.86	Guangdong	0.11	0.86	0.10	0.97	0.10	0.86
Anhui	0.01	0.03	0.01	0.14	0.01	0.38	Shanxi	0.01	0.07	0.01	0.03	0.01	0.10

3.2 Community detection

According to the investor and investee networks in Figure 1, this paper applies agglomerative hierarchical clustering method to conduct community detection and the results are as follows (see in Figure2). The results shows, from investor behavioral associative network's perspective, the investors' relations can be divided into 4 blocks in 2001. First block is the Southeast Asia including Macau, Thailand and the Philippines. Second block is combined with Canada, Australia, France, Netherland and Italy. Third block concludes Hong Kong, Taiwan, Japan, Korea, Singapore and its neighbors, UK, US and German. Nations that are not formed scale yet belong to the last block. Based on the above blocks, we can notice that, after2005, Hong Kong, Japan and the US's block relation remains the same. Singapore, Taiwan and Korea adjusted the investment scale and stretched the distance with core blocks, but they are still in the main investment block. While France, German and the UK, Canada's behavioral relations are integrating constantly. From investee behavioral associative network's perspective, because early investments are intensive, domestic investment-attracting relations are divided into three blocks. First is composed by Jiangsu, Zhejiang, Shanghai, Liaoning, Shandong, Guangdong and Fujian. It is a coastal block. Second is a middle block including Peking, Hebei, Hubei and Hunan. Third block collects provinces with lower investment-attraction. Then, after 2005, as the enlargement of investment scale, large block begins to absorb middle and west areas so as to reform a new block. Coastal block integrated with Tianjin, Shanxi, Hubei first and with

Sichuan, Chongqing as well as Henan to form core block. While middle block expanded to Anhui, Shanxi and so on.

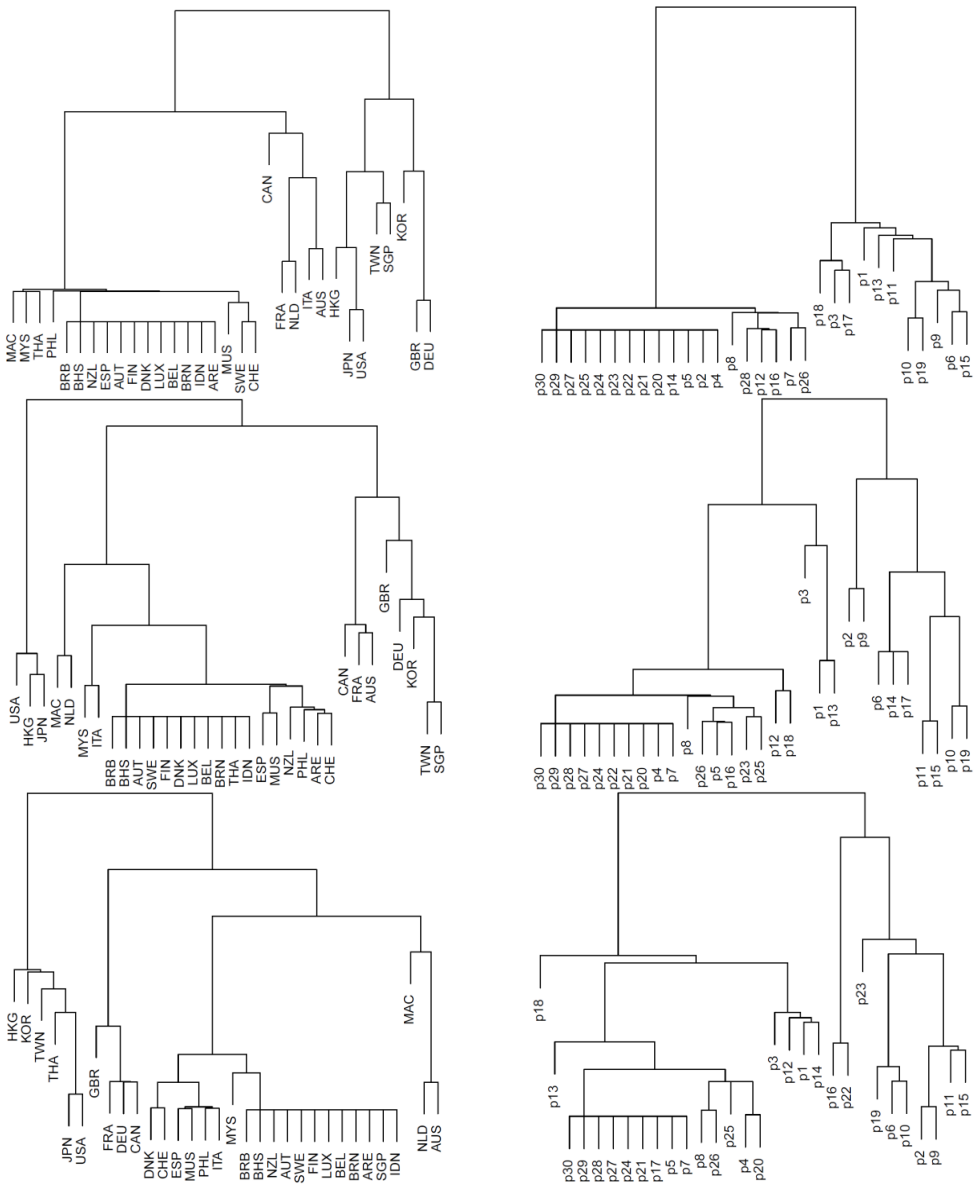

Figure 2. Community Detection of Investor and Investee Behavioral Associative Networks

4 CONCLUSIONS

Using complex network analysis method, this paper analyzes the structures and main factors which influences the formation of associative relationships of China's regional behavioral

associative networks of FDI. First by measuring network density, average path length, transitivity and other series of network feature indices and node centrality indices, this paper conduct exploration from overall and individual level. It depicts the basic feature and dynamic evolution rule of investor and investee behavioral associative relations. Then this paper uses agglomerative hierarchical clustering method to conduct community detection, and analyzes the community structure of regional behavioral associative network. It explores the investor and investee between 2001 and 2010 and concludes general investor and investee behavior features. The results are as follows. First, the regional behavioral associative networks have the "Small World" feature and the investments distribute unevenly. Second, the "Western Expansion" effect brought by the adjustment of FDI's structures is establishing, but the inland transmission effect distinguishes between eastern, northern region and south region. Third, the leading block of investors is consisting of Hong Kong, Japan and USA, while the leading block of investee takes the advantage of the inland transmission effect to promote a 'sandwich' mode of development among the eastern, middle and western regions. In the future, the author will use ERGM and other methods to analyze the factors that have interactive influence on the inter-regional FDI behavior relationship, so as to more effectively explore the reasons for the correlation between the investment behavior of the source area and the investment behavior of the destination.

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